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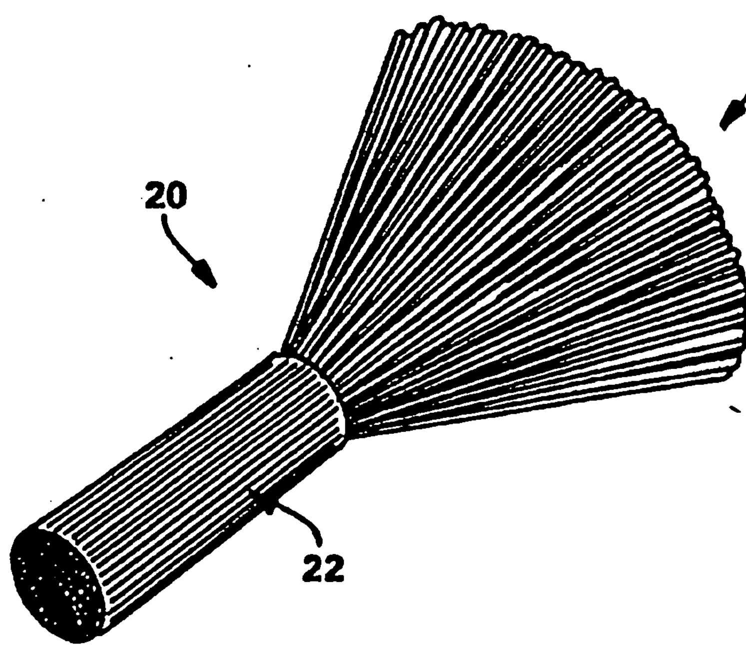
(54) Title: TRANSPORTING OF LIQUID BY A CAPILLARY FIBER STRUCTURE

(57) Abstract

A fiber structure for spontaneously transporting a liquid in a desired direction, said fiber structure being capable of interfiber liquid transport. The fiber structure comprises at least two fibers, wherein the fibers are wettable with a liquid to be contacted with the fiber structure, and a first zone and a second zone, wherein the first zone has an average capillary radius greater than the average capillary radius of the second zone. Also disclosed is a disposable absorbent product capable f absorbing discharged body liquids that includes the fiber structure.



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TRANSPORTING OF LIQUID BY A CAPILLARY FIBER STRUCTURE

Background of the Invention

Field of the Invention

The present invention relates to fiber structures for transporting a liquid in a desired direction. Specifically, the present invention relates to fiber structures having an average capillary radius gradient that results in spontaneous interfiber transport of a liquid in the direction of decreasing average capillary radius.

Description of the Related Art

The use of fibers to form various woven and nonwoven products is known. For example, it is known to use regenerated cellulose filaments having a collapsed hollow structure and a multi-limbed cross section. Such fibers possess a high capability of water imbibition. These fibers can be formed into woven fabrics like toweling and nonwoven fabrics and wadding such as diapers, sanitary napkins, tampons and swabs.

It is also known to use cellulosic fibers having a decitex of less than 5.0 and a multi-limbed cross section. The limbs have a length-to-width aspect ratio of at least 2:1. The fibers can be formed into woven, nonwoven, or knitted fabrics and are described as being especially useful for absorbent products.

When fiber structures, such as nonwoven webs, are employed in disposable absorbent products such as diapers, training pants, adult incontinent products, feminine care products, wound dressings, and the like, the simple ability to absorb a liquid is generally not sufficient to ensure optimum performance in a product. For example, during use, many personal care products are exposed to multiple insults of a liquid. In order to ensure proper absorption of subsequent insults, it is generally desired

that the first insult of liquid be not only absorbed but also transported within the absorbent products to areas remote from the point of insult.

Additionally, the ability of a fiber structure to transport a liquid is desirable for another reason. Specifically, when the fiber structure is to be employed in an absorbent structure in an absorbent product, it is often desirable to combine with the absorbent structure a high-absorbency material. Such high-absorbency materials are known to those skilled in the art and are generally capable of absorbing many times their weight in a liquid. Thus, much of the total absorbent capacity of an absorbent structure, employing such high-absorbency materials, results from the presence of the high-absorbency material. In order for the high-absorbency material to absorb a liquid, the liquid must come into contact with the high-absorbency material. If the absorbent structure including the high-absorbency material is not able to transport a liquid from the point of liquid application, all of the high-absorbency material must be placed in the general area where the liquid to be absorbed will be applied to the absorbent structure. This is not always desirable.

Specifically, when a high concentration of a high-absorbency material is localized in an absorbent structure, it is possible for gel blocking to occur. That is, the high-absorbency material can swell in the localized area to the extent that an essentially liquid-impermeable mass of high-absorbency material is formed. Should this occur, subsequent insults cannot be transported by the absorbent structure. Accordingly, it is often desirable to more evenly distribute the high-absorbency material in the absorbent structure. For this reason, it is desirable for the absorbent structure to be able to transport a liquid from a point of application to a high-absorbency material located remote from the point of application.

Summary of the Invention

It is desirable to provide a fiber structure capable of spontaneously transporting a liquid to points remote from the point of liquid application.

It is also desirable to provide a fiber structure capable of spontaneously transporting a liquid in a desired or specific direction.

These and other related goals are achieved in a fiber structure capable of transporting a liquid in a desired direction, said fiber structure being capable of spontaneous interfiber liquid transport. In one embodiment, the fiber structure comprises at least two fibers, wherein the fibers are wettable with a liquid to be contacted with the fiber structure, and a first zone and a second zone, wherein the first zone has an average capillary radius greater than the average capillary radius of the second zone.

In another aspect, it is desirable to provide a thin, disposable absorbent product, such as an infant diaper, which product employs an absorbent structure having a relatively small volume and yet has a relatively large liquid capacity.

In one embodiment, these goals are achieved in a disposable absorbent product comprising a backsheet, a liquid-permeable topsheet attached to the backsheet, and an absorbent structure located between the backsheet and the liquid-permeable topsheet, said absorbent structure comprising a crotch section, an end section, and a fiber structure, said fiber structure comprising at least two fibers, wherein the fibers are wettable with a liquid to be contacted with the fiber structure, and a first zone and a second zone, wherein the first zone has an average capillary radius greater than the average capillary radius of the second zone, and wherein the first zone is in contact with the absorbent structure crotch section and the second zone is in contact with the absorbent structure end section.

In another aspect, it is desirable to provide a method of spontaneously transporting a liquid in a desired direction in a fiber structure.

In one embodiment, these goals are achieved in a method for transporting liquid in a desired direction in a fiber structure. The method comprises contacting a liquid with a fiber structure, wherein the fiber structure comprises at least two fibers, wherein the fibers are wettable with the liquid contacted with the fiber structure, and a first zone and a second zone, wherein the first zone has an average capillary radius greater than the average capillary radius of the second zone, wherein the liquid is

contacted with the first zone of the fiber structure and wherein the liquid is transported from the first zone to the second zone.

Brief Description of the Drawings

Fig. 1 represents a disposable absorbent product according to the present invention.

Fig. 2 represents a fiber structure according to the present invention that comprises two zones of different average capillary radii.

Fig. 3 represents a fiber structure that comprises one zone of essentially constant capillary radii.

Fig. 4 represents a fiber structure according to the present invention that comprises a middle zone and two end zones of different average capillary radii.

Detailed Description of the Preferred Embodiments

As used herein, reference to interfiber liquid transport refers to the situation wherein a liquid moves through a structure of fibers as a result of capillaries formed by said fibers. The distance of interfiber liquid transport depends on the capillary pressure of the system. The capillary pressure of a cylindrical capillary is expressed by the equation:

$$P = \frac{2 \gamma \cos\theta}{r}$$

wherein P is the capillary pressure, γ is the surface tension of the liquid, θ is the liquid-fiber contact angle, and r is the capillary radius. With a given liquid, the capillary pressure (capillary force) increases with the cosine of the liquid-fiber contact angle and decreases with larger capillary radii so that smaller capillaries will generally transport a liquid farther through the interfiber capillaries as compared to a larger capillary.

Thus, when a liquid is contacted with a fiber structure having a relatively constant capillary radius, the liquid will be spontaneously transported within the fiber structure a distance that is dependent on the capillary pressure of the fiber structure. Such spontaneous

transport of the liquid will generally be in any direction away from the location where the liquid contacts the fiber structure.

In contrast to interfiber liquid transport, intrafiber liquid transport refers to the situation wherein a liquid is transported against a pressure along the length of an individual fiber as a result of a notch or channel defined by the surface of the individual fiber.

As used herein, reference to the contact angle formed between the liquid to be absorbed and transported and the material from which the fibers are formed may be determined by methods known to one skilled in the art as, for example, set forth by Good and Stromberg in "Surface and Colloid Science" Vol. 11 (Plenum Press, 1979).

As used herein, reference to the average capillary radius of a fiber structure, or a zone of a fiber structure, is meant to refer to an average of all capillary radii within the fiber structure or a zone of the fiber structure. The average capillary radii of a fiber structure, or a zone of a fiber structure, may be determined by methods known to one skilled in the art. For example, image analysis may be used to determine the equivalent pore area across a cross-sectional area of a zone of a fiber structure from which the average capillary radius of the zone may be determined. Other known methods for determining the average capillary radius of a fiber structure include using a capillary tension test or the use of a porosimeter.

As used herein, spontaneous interfiber liquid transport in a desired or specific direction is meant to refer to the situation wherein the interfiber liquid transport occurs essentially independently of any external forces or conditions, such as an externally applied pressure, gravity, or the like, but is essentially the result of the physical structure of the fiber structure itself. Applicants have discovered that such spontaneous interfiber liquid transport in a desired direction will occur within a fiber structure from a first zone of the fiber structure to a second zone of the fiber structure, wherein the first zone has an average capillary radius greater than the average capillary radius of the second zone. Such spontaneous interfiber liquid transport in a specific direction occurs within the fiber structure due to the difference in

capillary pressures between the first zone and the second zone. A fiber structure first zone, having a relatively larger average capillary radius, will have a smaller liquid capillary pressure than a fiber structure second zone, having a relatively smaller average capillary radius, so that a liquid in the first zone will spontaneously transport to the second zone due to the driving force caused by the difference in capillary pressures. Such spontaneous interfiber liquid transport in a specific direction may generally occur in any desired direction, such as horizontally, vertically, or at an angle.

As used herein, a "zone" of a fiber structure is meant to refer to a section or area of the fiber structure that is distinct from another zone or zones of the fiber structure by having a different average capillary radius from the other zone or zones. Generally, the fiber structures of the present invention will be unitary structures, such that the zones of the fiber structure will be immediately adjacent to each other and in liquid communication with each other, such that a liquid may be transported from one zone to another. Depending on the physical structure of a particular fiber structure of the present invention, the beginning and the end of adjacent zones may not be physically distinct and may sometimes be rather arbitrarily defined. However, it is important that any defined zone be distinct from an adjacent zone by having an average capillary radius that is different from the adjacent zone. A particular zone may have a constant capillary radius or radii or a variable capillary radius or radii along its length.

A zone of a fiber structure of the present invention will beneficially have a width of from about 0.5 inch to about 10 inches and suitably from about 1 inch to about 6 inches. A zone of a fiber structure of the present invention will beneficially have a length of from about 1 inch to about 10 inches and suitably from about 2 inches to about 8 inches.

The fiber structures of the present invention comprise at least two zones having different average capillary radii and may also comprise more than two zones having different average capillary radii. When a fiber structure comprises more than two zones, each of the zones may have different average capillary radii. Alternatively, several of the zones may have essentially equal average capillary radii, although such zones

should be separated from each other by other zones that have different average capillary radii. In one embodiment of the present invention, a fiber structure comprises a middle zone and two end zones, wherein the middle zone has an average capillary radius greater than the average capillary radius of each of the two end zones.

The capillary radii of the zones of the fiber structure should not be so large as to prevent spontaneous liquid transport from occurring due to a very low driving force. Suitably, the zones should have an average capillary radius that is smaller than about 200 micrometers in order for spontaneous liquid transport to occur. The capillary radii of the zones of the fiber structure should also not be so small as to prevent spontaneous liquid transport from occurring due to a very large drag force. Suitably, the zones should have an average capillary radius that is larger than about 0.1 micrometers in order for spontaneous liquid transport to occur.

As such, the average capillary radii of the zones of a fiber structure, such as each of a first and a second zones, are beneficially from about 0.1 micrometer to about 200 micrometers, suitably from about 1 micrometer to about 150 micrometers, and more suitably from about 5 micrometers to about 100 micrometers. However, as described herein, the average capillary radius of the first zone must be greater than the average capillary radius of the second zone in order to achieve the desired spontaneous interfiber liquid transport in a desired direction within the fiber structure.

Because the average capillary radius of the first zone needs to be greater than the average capillary radius of the second zone, the ratio of the average capillary radius of the first zone compared to the average capillary radius of the second zone will be greater than at least 1:1, and is beneficially greater than at least about 2:1, is suitably greater than at least about 3:1, and is more suitably greater than at least about 5:1.

Fig. 2 illustrates a fiber structure 20 formed from substantially aligned, individual fibers and comprising a first zone 21 and a second zone 22, wherein the first zone 21 has an average capillary radius

greater than the average capillary radius of the second zone 22. Accordingly, when a liquid is applied to the fiber structure 20 in the first zone 21, the fiber structure 20 is capable of spontaneous interfiber liquid transport of the liquid in a specific direction to second zone 22. That is, the liquid is spontaneously transported in the capillaries defined by the fibers forming the fiber structure 20 and is transported to second zone 22. The amount of the interfiber liquid transport occurring will depend on the amount of liquid applied and the capillary pressure difference between the two zones of the fiber structure system which is, as discussed above, dependent on capillary radius, surface tension of the liquid, and contact angle between the fibers and the liquid.

Fig. 3 illustrates a fiber structure 25 comprising essentially only one zone, wherein this zone has an average capillary radius that is essentially constant within the zone. When a liquid is applied to the fiber structure 25, the fiber structure 25 generally transports the liquid in the interfiber capillaries a lesser distance than that achieved with the fiber structure 20 in Fig. 2. Also, there is generally no specific direction to the spontaneous transport of the liquid contacted with fiber structure 25. For example, a liquid contacted with the middle portion 26 of fiber structure 25 will generally be transported towards both fiber structure ends 27.

Fig. 4 illustrates a fiber structure 30 comprising essentially three zones. The middle zone 32 has an average capillary radius greater than the average capillary radii of each of two end zones 31. The end zones 31 may have essentially equal average capillary radii or may have different average capillary radii. Accordingly, when a liquid is applied to the fiber structure 30 in the first zone 32, the fiber structure 30 is capable of spontaneous interfiber liquid transport of the liquid in a specific direction to each of the end zones 31. That is, the liquid is spontaneously transported in the capillaries defined by the fibers forming the fiber structure 30 and is transported to end zones 31. The amount of the interfiber liquid transport occurring will depend on the amount of liquid applied and the capillary pressure difference between the respective zones of the fiber structure system.

The fibers useful in forming the fiber structures of the present invention can be formed from any material capable of forming a fiber structure. As a general rule, the fibers are formed from a cellulose derivative such as rayon or cellulose acetate or from a synthetic polymeric material such as polyolefins, polyesters, polyamides, polyurethanes, and the like. The materials from which the fiber can be formed may be either wettable or nonwettable. As used herein, "wettable" refers to fibers having a liquid-in-air contact angle of less than 90°, wherein the liquid contacting the fiber is suitably a liquid such as water, synthetic urine, urine, menses, blood, or a 0.9 weight percent aqueous saline solution. "Nonwettable" refers to fibers having a liquid-in-air contact angle greater than 90°. The liquid-in-air contact angle of a fiber may be determined, for example, as set forth by Good and Stromberg in "Surface and Colloid Science" Vol. 11, (Plenum Press, 1979). When the fibers are formed from nonwettable material, the fibers must generally be treated to provide them with a wettable surface. Methods of providing nonwettable materials with a wettable surface are known. Exemplary of such a method is the application of a surfactant or other wetting agent to the fibers.

Similarly, if a wettable fiber having a contact angle of less than 90° is desired to be rendered more wettable, to thereby decrease its contact angle with respect to a given liquid, it is possible to treat the wettable fiber with a surfactant or other wetting agent to impart a more wettable surface. The wetting treatment is desirably nonfugitive. That is, the surface treatment desirably does not wash off the surface of the fiber with the first liquid insult or contact. For the purposes of this application, a surface treatment on a generally nonwettable fiber will be considered to be nonfugitive when a majority of the fibers demonstrate a liquid-in-air contact angle of less than 90° for three consecutive contact angle measurements, with drying between each measurement. That is, the same fiber is subjected to three separate contact angle determinations and, if all three of the contact angle determinations indicate a contact angle of liquid-in-air of less than 90°, the surface treatment on the fiber will be considered to be nonfugitive. If the surface treatment is fugitive, the surface treatment will tend to wash off of the fiber during the first contact angle measurement, thus,

exposing the nonwettable surface of the underlying fiber and will demonstrate subsequent contact angle measurements greater than 90°.

The fibers used herein may generally be of any desired cross-sectional shape including circular, oval, multi-lobed, or other shapes known to those skilled in the art. Methods of forming fibers are also known to those skilled in the art. As a general rule, fibers formed from a synthetic polymeric material are generally prepared by extruding the fibers through a die orifice generally corresponding to the desired shape. Such a method is described in U.S. Patent 2,945,739 issued July 19, 1960, to Lehmicke, or in Japanese Kokoku Patent No. SHO 62[1987]-53605. If the fiber is to be formed from a cellulosic derivative, such as rayon, the fibers can be formed from conventional viscose and are conveniently spun from standard viscose compositions using standard viscose spinning conditions. Such a method is described in European Patent Application 0 301 874 A2 published February 1, 1989. Alternatively, the fiber may be formed from cellulose acetate. Further, the fiber may be formed by twisting two or more fibers together.

The fibers according to the present invention generally have a diameter or width of from about 0.25 micrometer to about 500 micrometers, suitably of from about 0.5 micrometer to about 40 micrometers.

Fiber structures according to the present invention can suitably be formed in any manner capable of forming fiber structures known to those skilled in the art. For example, the fiber structure may be formed through a carding process, rando process, spunbond process, needlepunch process, and the like, and may be in the form of a web, bundle, sheet or the like. The fiber structures according to the present invention suitably have: a density of from about 0.01 gram per cubic centimeter to about 0.5 gram per cubic centimeter, more suitably of from about 0.05 gram per cubic centimeter to about 0.2 gram per cubic centimeter; a thickness of from about 0.5 micrometer to about 0.05 meter, more suitably from about 50 micrometers to about 0.015 meter; a length of from about 0.05 meter to about 0.4 meter, more suitably from about 0.075 meter to about 0.25 meter. The fiber structures of the present invention will comprise at least two fibers, suitably at least about 10 fibers, and more suitably at least about 50 fibers.

The fiber structures according to the present invention are suited to transfer many liquids, such as water, saline, and synthetic urine, and body liquids, such as urine, menses, and blood, and are suited for use in disposable absorbent products, such as diapers, adult incontinent products, and bed pads; in catamenial devices, such as sanitary napkins and tampons; and in other absorbent products, such as wipes, bibs, wound dressings, and surgical capes or drapes. Accordingly, in another aspect, the present invention relates to a disposable absorbent product comprising a fiber structure as described herein.

Use of the described fiber structures in disposable absorbent products allows for the formation of a disposable absorbent product which is able to rapidly receive a discharged liquid and yet which product is thin. Typically, the fiber structure will be incorporated into a disposable absorbent product in the form of an absorbent structure. Such disposable absorbent products generally comprise a liquid-permeable topsheet, a backsheet attached to the topsheet, and an absorbent structure, such as an absorbent structure comprising the fiber structure of the present invention, located between the topsheet and backsheet.

Exemplary disposable absorbent products are generally described in US-A-4,710,187; US-A-4,762,521; US-A-4,770,656; US-A-4,798,603; and U.S. Serial No. 08/096,654, filed July 22, 1993, in the name of Hansen et al., which references are incorporated herein by reference.

The fiber structure is present in an absorbent structure or product of the present invention in an amount effective to spontaneously transfer in a desired direction a desired amount of liquid so as to result in the absorbent structure or product being able to absorb a desired amount of liquid. The fiber structure is beneficially present in an absorbent structure of the present invention in an amount of from about 0.1 to about 100 weight percent, based on the total weight of the absorbent structure.

The fiber structures of the present invention beneficially exhibit an improvement in flux (volume delivery over time) of a liquid contacted with the fiber structure as compared to a fiber structure having only a single zone of essentially constant average capillary radius. A fiber

structure of the present invention exhibits a flux of a liquid contacted with the fiber structure that is beneficially at least about 10 percent greater, suitably at least about 20 percent greater, and more suitably at least about 30 percent greater than a fiber structure having only a single zone of essentially constant average capillary radius, wherein the average capillary radius of the fiber structure having only a single zone is similar to the average capillary radius of one of the zones of the fiber structure of the present invention.

Because the fiber structures present in the absorbent structures of the present invention can transfer relatively large quantities of liquid throughout the absorbent structure so as to utilize the entire absorbent structure, the absorbent structures of the present invention can be relatively thin and light weight, have a relatively small volume, and still function in a desirable manner.

An absorbent structure of the present invention suitably comprises the fiber structure of the present invention as well as a fibrous matrix comprising a hydrogel-forming polymeric material wherein the fibrous matrix constrains or entraps the hydrogel-forming polymeric material.

Hydrogel-forming polymeric materials include, for example, carboxymethylcellulose, alkali metal salts of polyacrylic acids, polyacrylamides, polyvinyl alcohol, ethylene maleic anhydride copolymers, polyvinyl ethers, hydroxypropylcellulose, polyvinyl morpholinone, polymers and copolymers of vinyl sulfonic acid, polyacrylates, polyacrylamides, polyvinyl pyridine, and the like. Other suitable hydrogel-forming polymeric materials include hydrolyzed acrylonitrile grafted starch, acrylic acid grafted starch, and isobutylene maleic anhydride copolymers and mixtures thereof. The hydrogel-forming polymeric materials are suitably lightly cross-linked to render the material substantially water insoluble. Cross-linking may, for example, be by irradiation or by covalent, ionic, Van der Waals, or hydrogen bonding. Suitable hydrogel-forming polymeric materials are available from various commercial vendors such as The Dow Chemical Company, Celanese Corporation, Allied-Colloid, and Stockhausen. Typically, the hydrogel-forming polymeric material is capable of absorbing at least about fifteen times its weight in water and preferably is capable of

absorbing at least about 25-30 times its weight in water. The hydrogel-forming polymeric material can be present in the fibrous matrix in an amount of from about 1 to about 95 weight percent, suitably of from about 5 to about 60 weight percent based on total weight of the fibrous matrix.

The hydrogel-forming polymeric material is suitably in liquid communication with the fiber structure in an area of interfiber liquid transport. As used herein, a hydrogel-forming polymeric material will be considered to be in liquid communication with the fiber structure, in an area of interfiber liquid transport, when a liquid present in the area of interfiber liquid transport can flow into contact with the hydrogel-forming polymeric material.

For example, the hydrogel-forming polymeric material may be present in the absorbent structure in an area of interfiber liquid transport. Alternatively, the hydrogel-forming polymeric material may be present in a pouch or a second absorbent structure, which pouch or second absorbent structure is, in turn, in contact with the area of interfiber liquid transport.

Applicants have discovered that, when the hydrogel-forming polymeric material is in liquid communication with the fiber structure in an area of interfiber liquid transport, the hydrogel-forming polymeric material may contact the liquid transported by the fiber structure. When the hydrogel-forming polymeric material is in contact with the liquid in an area of interfiber liquid transport, the hydrogel-forming polymeric material is able to absorb the liquid, thus, improving utilization of the hydrogel-forming polymeric material and allowing continued interfiber liquid transport in a desired direction. For example, Applicants have found that, when a hydrogel-forming polymeric material capable of, for example, absorbing twenty times its weight in a liquid is in contact with the liquid in the area of interfiber liquid transport, the fiber structure will continue to transport liquid via spontaneous interfiber liquid transport, in a desired direction, to the hydrogel-forming polymeric material until the absorption capacity of the hydrogel-forming polymeric material is reached or until there is no more available liquid

for the fiber structure to transport in a desired direction. This phenomenon is important for several reasons.

Use of the fiber structures described herein allows for improved utilization of hydrogel-forming polymeric material present in or in liquid communication with the fiber structure or an absorbent structure. That is, it is possible to disperse a given amount of hydrogel-forming polymeric material in the absorbent structure (or in liquid communication with the fiber structure) over a greater area when a fiber structure having an average capillary radius gradient is used than when a fiber structure having an essentially constant average capillary radius is used.

As used herein, the term "fiber" or "fibrous" is meant to refer to a particulate material wherein the length to diameter ratio of such particulate material is greater than about 10. Conversely, a "nonfiber" or "nonfibrous" material is meant to refer to a particulate material wherein the length to diameter ratio of such particulate material is about 10 or less.

A wide variety of natural and synthetic fibers can be employed in the preparation of the fibrous matrix of the present invention. Illustrative fibers include, but are not limited to, wood and wood products, such as wood pulp fibers, cellulose or cellulose acetate flocs, cotton linter flocs and the like, inorganic fibers, synthetic fibers such as nylon flocs, rayon flocs, polyacrylonitrile fibers, and the like.

It is also possible to use mixtures of one or more natural fibers, or one or more synthetic fibers, or combinations of the two. Preferred fibers are those which are wettable in nature. However, nonwettable fibers can also be used.

Fibrous matrixes for incorporation into an absorbent structure are generally well known. A fibrous matrix may take the form of, for example, a batt of comminuted wood pulp fluff, a tissue layer, a hydroentangled pulp sheet, a mechanically softened pulp sheet, or of a web structure comprising an entangled fibrous mass formed, for example, from an extruded thermoplastic composition. Suitably, the fibrous matrix

is formed so as to constrain or entrap the hydrogel-forming polymeric material within, or onto, its structure. The hydrogel-forming polymeric material may be incorporated into or onto the fibrous matrix either during or after the formation of the general form of the fibrous matrix.

Suitably, the fiber matrix has a basis weight ranging from about 0.025 grams per square meter of fiber matrix material to about 400 grams per square meter of fiber matrix material.

Suitably, the fiber matrix has a density ranging from about 0.05 grams per cubic centimeter of fiber matrix material to about 0.5 grams per cubic centimeter of fiber matrix material.

Suitably, the fibers comprising the fiber matrix have a fiber length ranging from about 0.1 centimeter to about 3.0 centimeters.

The fibrous matrix may be formed through an air-laying process, a spunbond or meltblown process, a carding process, a wet-laid process, or through essentially any other process means, known to those skilled in the art, for forming a fibrous matrix.

Methods of incorporating the hydrogel-forming polymeric material into the fibrous matrix are known to those skilled in the art. Suitable methods include incorporating the hydrogel-forming polymeric material into the matrix during formation of the matrix, such as by air-laying the fibers of the fibrous matrix and the hydrogel-forming polymeric material at the same time or wet-laying the fibers of the fibrous matrix and the hydrogel-forming polymeric material at the same time. It is preferable that the hydrogel-forming polymeric material be generally uniformly distributed within the fibrous matrix. However, the hydrogel-forming polymeric material may be nonuniformly distributed as long as the desired absorbent properties of the absorbent structure are still achieved. Alternatively, it is possible to apply the hydrogel-forming polymeric material to the fibrous matrix after formation of the fibrous matrix. Other methods include sandwiching the hydrogel-forming polymeric material between two sheets of material, at least one of which is fibrous and liquid permeable. The hydrogel-forming polymeric material may be

generally uniformly located between the two sheets of material or may be located in discrete pockets formed by the two sheets.

The fibrous matrix may be in the form of a single, integrally formed layer or of a composite comprising multiple layers. If the fibrous matrix comprises multiple layers, the layers are preferably in liquid communication with one another such that a liquid present in one fibrous layer can flow or be transported to the other fibrous layer. For example, the fibrous layers may be separated by cellulosic tissue wrap sheets known to those skilled in the art.

When the fibrous matrix comprises a single, integrally formed layer, the concentration of hydrogel-forming polymeric material may increase along the thickness of the fibrous matrix in a gradual, nonstepwise fashion or in a more stepwise fashion. Similarly, the density may decrease through the thickness in a nonstepwise manner or in a stepwise manner.

The absorbent structures of the present invention may generally be of any size or dimension as long as the absorbent structure exhibits the desired absorbent characteristics as described herein.

The absorbent structure of the present invention may also be used or combined with other absorbent structures, with the absorbent structure of the present invention being used as a separate layer or as an individual zone or area within a larger, composite absorbent structure. The absorbent structure of the present invention may be combined with other absorbent structures by methods well known to those skilled in the art, such as by using adhesives or simply by layering the different structures together and holding together the composite structures with, for example, tissue.

In one embodiment of the present invention, a disposable absorbent product is provided, which disposable absorbent product comprises a liquid-permeable topsheet, a backsheet attached to the topsheet, and an absorbent structure comprising a fiber structure of the present invention, wherein the absorbent structure is positioned between the topsheet and the backsheet.

While one embodiment of the invention will be described in terms of the use of a fiber structure in an infant diaper, it is to be understood that the fiber structure is equally suited for use in other disposable absorbent products known to those skilled in the art.

Fig. 1 illustrates a disposable diaper 1 according to one embodiment of the present invention. Disposable diaper 1 includes a backsheet 2, a topsheet 4, and an absorbent structure 6, located between the backsheet 2, and the topsheet 4. Absorbent structure 6 is an absorbent structure according to the present invention. Specifically, in the illustrated embodiment, absorbent structure 6 comprises a fiber structure 8 of the present invention.

Those skilled in the art will recognize materials suitable for use as the topsheet and backsheet. Exemplary of materials suitable for use as the topsheet are liquid-permeable materials, such as spunbonded polypropylene or polyethylene having a basis weight of from about 15 to about 25 grams per square meter. Exemplary of materials suitable for use as the backsheet are liquid-impervious materials, such as polyolefin films, as well as vapor-pervious materials, such as microporous polyolefin films.

Absorbent products and structures, according to all aspects of the present invention, are generally subjected during use to multiple insults of a body liquid. Accordingly, the absorbent products and structures are desirably capable of absorbing multiple insults of body liquids in quantities to which the absorbent products and structures will be exposed during use. The insults are generally separated from one another by a period of time.

Examples

Round bundles of aligned fibers, often used as cigarette filter materials, were obtained from Hoechst-Celanese Corporation. The fibers were trilobal and Y-shaped, had a denier of 3, and were prepared from wettable cellulose acetate. The fiber bundle was in a rod form, as shown in Fig. 3, with a paper wrapper outer cover. The rods were about 100 millimeters long with a diameter of about 8 millimeters.

The rods were cut to about 50 millimeter lengths, and the paper wrapper outer cover was removed from about 40 millimeters of such cut rod lengths. The unwrapped 40 millimeter lengths were "fanned out", as shown in Fig. 1, so that the far end of the fanned out zone was relatively flat and had a width of about 50 millimeters. The unwrapped, fanned-out zone had relatively larger capillary radii as compared to the wrapped zone which had relatively smaller capillary radii, thus, resulting in a capillary radius gradient between the two zones.

Example 1: Samples of the prepared fiber bundles were laid horizontally on a bench top and 5 drops of colored water were placed on the unwrapped, fanned-out zone of the fiber bundle. The liquid was observed to spontaneously transport to the wrapped zone of the fiber bundle (from low to high capillary pressure).

Example 2: A sample of the prepared fiber bundles was used. The end of the wrapped zone was moistened with water so that a hydrogel-forming polymeric material (a poly(acrylic acid) polymer, obtained from The Dow Chemical Company under the trade designation DRYTECH(TM) 533), adhered when the wrapped end zone was dipped into a supply of the hydrogel-forming polymeric material. The prepared structure was laid flat on a bench top. However, the geometry of the fiber structure, comprising a relatively flat, unwrapped zone and a round wrapped zone with hydrogel-forming polymeric material adhered to its end, resulted in a slight slope of about 5 millimeters upward from the unwrapped zone end to the wrapped zone end. Five drops of colored water were placed on the unwrapped, fanned-out zone of the fiber bundle. The liquid was observed to spontaneously transport, against gravity, to the wrapped zone of the fiber bundle. The hydrogel-forming polymeric material absorbed the colored water and drew any excess colored water from the unwrapped zone such that the unwrapped zone became dry to the touch within about 30 seconds.

Example 3: A full-length, 100 millimeter wrapped fiber bundle had the middle 80 millimeters of wrap paper removed, leaving about 10 millimeters of wrapped fibers at each end. The fibers in the middle, unwrapped 80 millimeter zone were fanned out to a diameter of about 50 millimeters, creating a fiber bundle having a zone with relatively larger capillary

radii as compared to the wrapped end zones. The fiber bundle was place horizontally on a bench top and colored water was added dropwise to the middle of the fiber bundle in the unwrapped zone. The colored water was observed to spontaneously transport to both wrapped end zones.

Example 4: Hydrogel-forming polymeric material was adhered to both wrapped zone ends of a fiber bundle, similar to the fiber bundle used in Example 3, by using a procedure similar to that described in Example 2. Colored water was added dropwise to the middle of the fiber bundle in the unwrapped zone. The colored water was observed to spontaneously transport to both wrapped end zones. The hydrogel-forming polymeric material absorbed the colored water and drew any excess colored water from the unwrapped zone such that the unwrapped zone became dry to the touch within about 30 seconds.

Example 5: Round bundles were prepared from aligned sliver fibers. The fibers were trilobal and were prepared from rayon with a glycerine finish as obtained from Courtaulds Inc. The fibers were aligned by forming a sliver and were encased in a shrink wrap outer cover. The fiber bundles were in a rod form, as shown in Fig. 3. The rods were about 50 millimeters long with a diameter of about 13 millimeters. For one of the samples, half of the outer cover was cut open and the fibers were expanded to a larger capillary size so as to create two zones of varying average capillary radii as shown in Fig. 2. As determined by image analysis, the end of the wrapped zone was found to have an average capillary radius of about 18 micrometers, and the end of the expanded zone was found to have an average capillary radius of about 49 micrometers. Another sample was left as a rod of one zone with an essentially uniform capillary radius of about 18 micrometers. The two sample fiber structures were then compared as to liquid wicking for both vertical and horizontal wicking along the length of the fiber structure. For the vertical wicking test, the fiber structure with two zones wicked colored water the 50 millimeter height, from the unwrapped zone to the wrapped zone, in about 5 seconds, while the fiber structure with one zone wicked colored water the 50 millimeter height in about 12 seconds. For the horizontal wicking test, the fiber structure with two zones wicked colored water the 50 millimeter length, from the unwrapped zone to the

wrapped zone, in about 5 seconds, while the fiber structure with one zone wicked colored water the 50 millimeter length in about 120 seconds.

Thus, it is seen that fiber structures having at least two zones having different average capillary radii as described by the present invention are capable of improved liquid transport as compared to fiber structures having only a single zone having an essentially constant average capillary radius. When a high-absorbency material is in liquid communication with the area of spontaneous, interfiber liquid transport, such as the second zone, the high-absorbency material is found to be effective in absorbing the transported liquid within the second zone so as to provide a means for continued spontaneous liquid transport from the first zone to the second zone.

While the present invention has been described in particular reference to several preferred embodiments, the present invention is susceptible of being embodied with various alterations and modifications which may differ, particularly from those that have been described in the preceding specification. These variations and alterations are possible without departing from the described invention.

What is claimed is:

1. A fiber structure capable of spontaneous interfiber transport of a liquid in a desired direction, wherein the fiber structure comprises at least two fibers wettable with a liquid to be contacted with the fiber structure and, wherein the fiber structure comprises a first zone and a second zone, wherein the first zone has an average capillary radius greater than the average capillary radius of the second zone.

2. The fiber structure of claim 1 wherein the liquid to be contacted with the fiber structure is water, synthetic urine, urine, menses, blood, or a 0.9 weight percent aqueous saline solution.

3. The fiber structure of claim 2 wherein the liquid to be contacted with the fiber structure is urine, menses, or blood.

4. The fiber structure of claim 2 wherein the liquid to be contacted with the fiber structure is water or a 0.9 weight percent aqueous saline solution.

5. The fiber structure of claim 1 wherein the average capillary radii of the first zone and the second zone of the fiber structure are from about 0.1 micrometer to about 200 micrometers.

6. The fiber structure of claim 5 wherein the average capillary radii of the first zone and the second zone of the fiber structure are from about 1 micrometer to about 150 micrometers.

7. The fiber structure of claim 6 wherein the average capillary radii of the first zone and the second zone of the fiber structure are from about 5 micrometers to about 100 micrometers.

8. The fiber structure of claim 1 wherein the ratio of the average capillary radius of the first zone compared to the average capillary radius of the second zone is greater than at least about 2:1.

9. The fiber structure of claim 8 wherein the ratio of the average capillary radius of the first zone compared to the average capillary radius of the second zone is greater than at least about 3:1.

10. The fiber structure of claim 9 wherein the ratio of the average capillary radius of the first zone compared to the average capillary radius of the second zone is greater than at least about 5:1.

11. The fiber structure of claim 1 wherein the fibers are prepared from rayon, cellulose acetate, polyolefin, polyester, polyamide, or polyurethane.

12. The fiber structure of claim 1 wherein the fibers have a diameter of from about 0.25 micrometer to about 500 micrometers.

13. The fiber structure of claim 1 wherein the fiber structure has a length of from about 0.05 meter to about 0.4 meter.

14. The fiber structure of claim 1 wherein the fiber structure comprises a bundle of substantially aligned, individual fibers.

15. The fiber structure of claim 14 wherein the fiber structure comprises at least about 10 fibers.

16. The fiber structure of claim 15 wherein the fiber structure comprises at least about 50 fibers.

17. The fiber structure of claim 1 wherein the fiber structure comprises at least 3 zones.

18. The fiber structure of claim 17 wherein the fiber structure comprises a middle zone and two end zones, wherein the middle zone has an average capillary radius greater than the average capillary radii of each of the two end zones.

19. The fiber structure of claim 17 wherein the two end zones have essentially equal average capillary radii.

20. A disposable absorbent product capable of absorbing discharged body liquids, said absorbent product comprising:

a backsheet;

a liquid-permeable topsheet attached to the backsheet; and

an absorbent structure located between the backsheet and the liquid-permeable topsheet, said absorbent structure comprising a crotch section, an end section, and a fiber structure, said fiber structure comprising at least two fibers wettable with a liquid to be contacted with the fiber structure, and wherein the fiber structure comprises a first zone and a second zone, wherein the first zone has an average capillary radius greater than the average capillary radius of the second zone, and wherein the first zone is in contact with the absorbent structure crotch section and the second zone is in contact with the absorbent structure end section.

21. The disposable absorbent product of claim 20 wherein the liquid to be contacted with the fiber structure is water, synthetic urine, urine, menses, blood, or a 0.9 weight percent aqueous saline solution.

22. The disposable absorbent product of claim 21 wherein the liquid to be contacted with the fiber structure is urine, menses, or blood.

23. The disposable absorbent product of claim 21 wherein the liquid to be contacted with the fiber structure is water or a 0.9 weight percent aqueous saline solution.

24. The disposable absorbent product of claim 20 wherein the average capillary radii of the first zone and the second zone of the fiber structure are from about 0.1 micrometer to about 200 micrometers.

25. The disposable absorbent product of claim 24 wherein the average capillary radii of the first zone and the second zone of the fiber structure are from about 1 micrometer to about 150 micrometers.

26. The disposable absorbent product of claim 25 wherein the average capillary radii of the first zone and the second zone of the fiber structure are from about 5 micrometers to about 100 micrometers.

27. The disposable absorbent product of claim 20 wherein the ratio of the average capillary radius of the first zone compared to the average capillary radius of the second zone is greater than at least about 2:1.

28. The disposable absorbent product of claim 27 wherein the ratio of the average capillary radius of the first zone compared to the average capillary radius of the second zone is greater than at least about 3:1.

29. The disposable absorbent product of claim 28 wherein the ratio of the average capillary radius of the first zone compared to the average capillary radius of the second zone is greater than at least about 5:1.

30. The disposable absorbent product of claim 20 wherein the fibers are prepared from rayon, cellulose acetate, polyolefin, polyester, polyamide, or polyurethane.

31. The disposable absorbent product of claim 20 wherein the fibers have a diameter of from about 0.25 micrometer to about 500 micrometers.

32. The disposable absorbent product of claim 20 wherein the fiber structure has a length of from about 0.05 meter to about 0.4 meter.

33. The disposable absorbent product of claim 20 wherein the fiber structure comprises a bundle of substantially aligned, individual fibers.

34. The disposable absorbent product of claim 33 wherein the fiber structure comprises at least about 10 fibers.

35. The disposable absorbent product of claim 34 wherein the fiber structure comprises at least about 50 fibers.

36. The disposable absorbent product of claim 20 wherein the fiber structure comprises at least 3 zones.

37. The disposable absorbent product of claim 36 wherein the fiber structure comprises a middle zone and two end zones, wherein the middle

zone has an average capillary radius greater than the average capillary radii of each of the two end zones.

38. The disposable absorbent product of claim 20 wherein the absorbent structure further comprises a fibrous matrix comprising a hydrogel-forming polymeric material.

39. The disposable absorbent product of claim 38 wherein said hydrogel-forming polymeric material is in liquid communication with said fiber structure in an area of interfiber liquid transport.

40. The disposable absorbent product of claim 38 wherein said hydrogel-forming polymeric material is carboxymethylcellulose, an alkali metal salt of polyacrylic acid, polyacrylamide, polyvinyl alcohol, an ethylene maleic anhydride copolymer, polyvinyl ether, hydroxypropylcellulose, polyvinyl morpholinone, a polymer of vinyl sulfonic acid, polyacrylate, polyacrylamide, or polyvinyl pyridine.

41. A method for transporting liquid in a fiber structure comprising contacting a liquid with a fiber structure, wherein the fiber structure comprises at least two fibers, wettable with the liquid contacted with the fiber structure, and a first zone and a second zone, wherein the first zone has an average capillary radius greater than the average capillary radius of the second zone, wherein the liquid is contacted with the first zone of the fiber structure and wherein the liquid is transported from the first zone to the second zone.

42. The method of claim 41 wherein the liquid to be contacted with the fiber structure is water, synthetic urine, urine, menses, blood, or a 0.9 weight percent aqueous saline solution.

43. The method of claim 42 wherein the liquid to be contacted with the fiber structure is urine, menses, or blood.

44. The method of claim 43 wherein the liquid to be contacted with the fiber structure is water or a 0.9 weight percent aqueous saline solution.

45. The method of claim 41 wherein the average capillary radii of the first zone and the second zone of the fiber structure are from about 0.1 micrometer to about 200 micrometers.

46. The method of claim 45 wherein the average capillary radii of the first zone and the second zone of the fiber structure are from about 1 micrometer to about 150 micrometers.

47. The method of claim 46 wherein the average capillary radii of the first zone and the second zone of the fiber structure are from about 5 micrometers to about 100 micrometers.

48. The method of claim 41 wherein the ratio of the average capillary radius of the first zone compared to the average capillary radius of the second zone is greater than at least about 2:1.

49. The method of claim 48 wherein the ratio of the average capillary radius of the first zone compared to the average capillary radius of the second zone is greater than at least about 3:1.

50. The method of claim 49 wherein the ratio of the average capillary radius of the first zone compared to the average capillary radius of the second zone is greater than at least about 5:1.

51. The method of claim 41 wherein the fibers are prepared from rayon, cellulose acetate, polyolefin, polyester, polyamide, or polyurethane.

52. The method of claim 41 wherein the fibers have a diameter of from about 0.25 micrometer to about 500 micrometers.

53. The method of claim 41 wherein the fiber structure has a length of from about 0.05 meter to about 0.4 meter.

54. The method of claim 41 wherein the fiber structure comprises a bundle of substantially aligned, individual fibers.

55. The method of claim 54 wherein the fiber structure comprises at least about 10 fibers.

56. The method of claim 55 wherein the fiber structure comprises at least about 50 fibers.

57. The method of claim 41 wherein the fiber structure comprises at least 3 zones.

58. The method of claim 57 wherein the fiber structure comprises a middle zone and two end zones, wherein the middle zone has an average capillary radius greater than the average capillary radii of each of the two end zones.

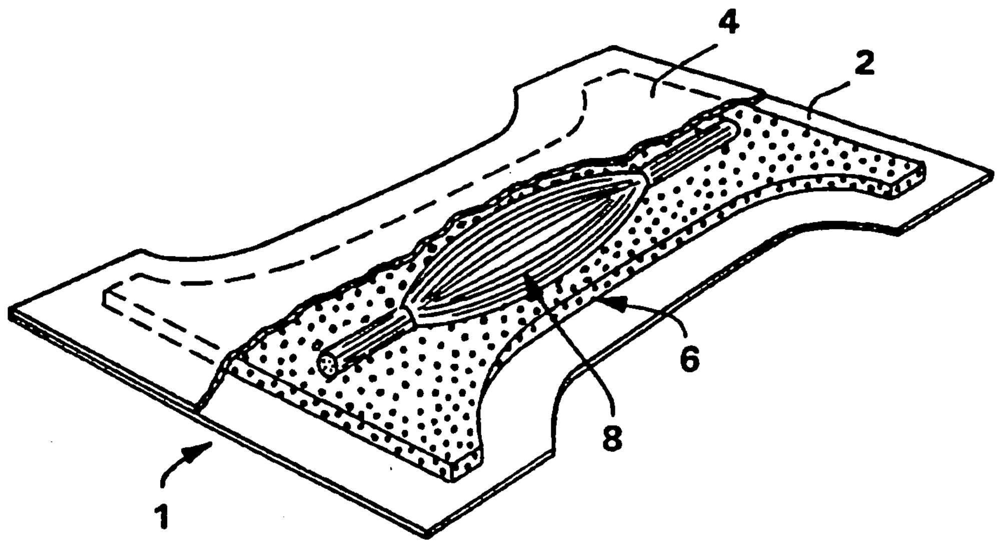

FIG. 1

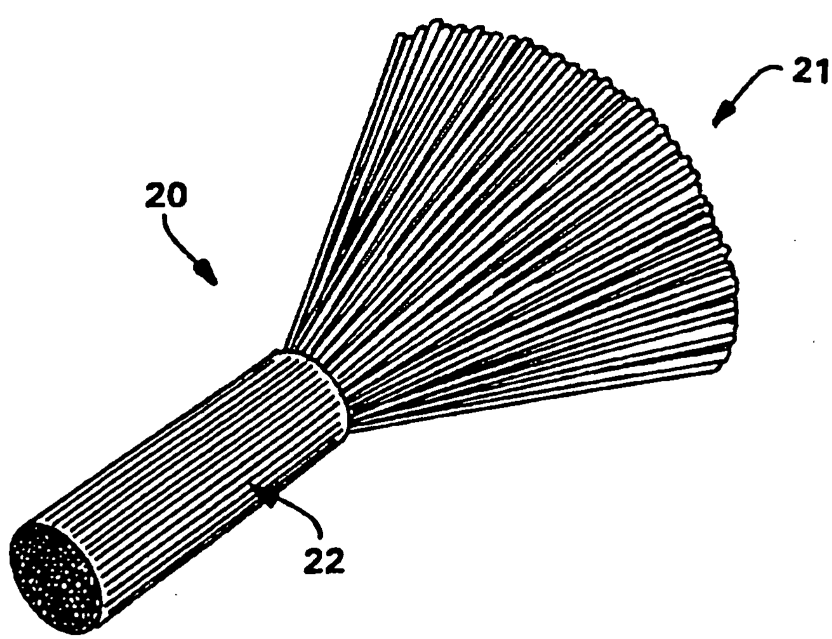

FIG. 2

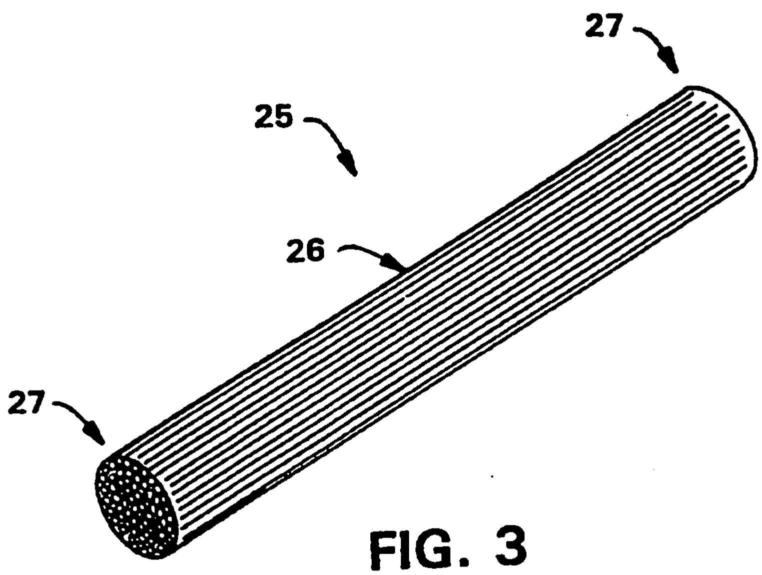

FIG. 3

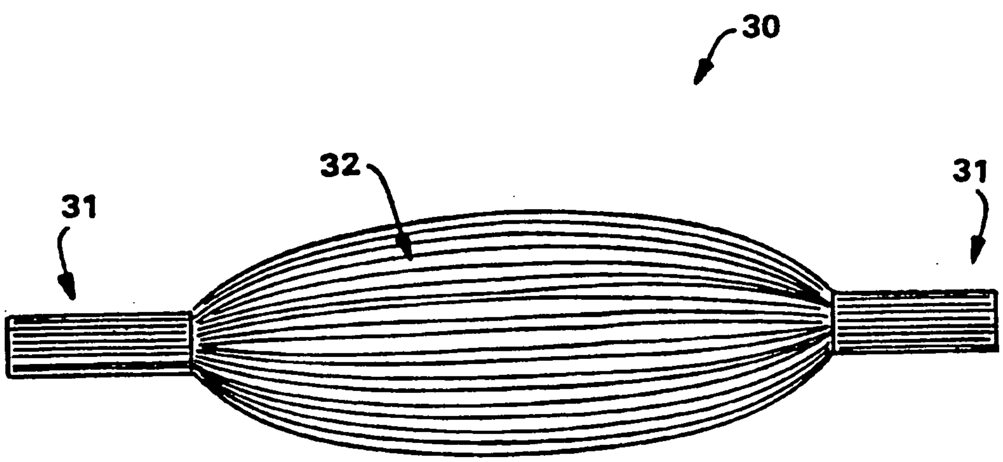

FIG. 4

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 95/08896

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 A61F13/46

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 A61F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP,A,0 597 498 (KIMBERLY-CLARK CORPORATION) 18 May 1994 see the whole document ---	1-4, 8-11, 14-17, 41-44, 49-51, 54-57
X	EP,A,0 391 814 (EASTMAN KODAK COMPANY) 10 October 1990 see figure 24; example 19 ---	1-4,14, 17,19, 41-44, 53,54
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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"P" document published prior to the international filing date but later than the priority date claimed

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 December 1995	21. 12. 95

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Douskas, K

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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		EP-A- 0312118	19-04-89
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Information on patent family members

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